IEA Solar Heating and Cooling Programme

TASK 18 : Advanced Glazing and Associated Materials for Solar and Building Applications

Case Study B9

Frame and Edge Seal Technology

Final Project Report

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1. INTRODUCTION

In windows and in solar collectors and solar walls, the glazing is mounted in a frame, normally made in wood, plastic (typically PVC) or metal (typically aluminium or steel). The frame protects the vulnerable edges of the glazing and provides structural strength. In multipane windows, the glazing is normally incorporated as a sealed unit, with metal or plastic spacer bars along the edges, and sealants used as adhesives and cavity seal.

The thermal transfer in such a component is quite complex; the frame and the edge seal normally constituting thermal bridges. The overall U-value for the whole component is strongly dependent on the thermal properties of the frame and the edge seal, and the dimensions, in addition to the centre-of-glass U-value. Therefore, as advanced glazings with improved thermal properties are introduced, a parallel development of the frame and edge seal is required, in order to reap the full benefit of new glazing technologies.

Therefore, a special case study group was established within the materials development and testing subtask for frame and edge seal technology compatible with new advanced glazing. This is in agreement with the overall task and subtask objectives, which call for development of the engineering and architectural basis for using these new technologies, and includes investigation of whole components.

2. OBJECTIVES AND WORKPLAN

The objectives of the Subtask B Case Study Project B9 "Frame and Edge Seal Technology" was at the outset formulated thus:

> "To investigate the influence of the frame and glazing edge seal on the total U-value of a glazing system, to develop improved test and calculation methods, and the design, construction and testing of low thermal loss frames for use in advanced glazing applications."

In a revised workplan adopted later, the objective was simplified to:

> "To further the development of low thermal loss frame and edge seals compatible with high performance advanced glazings”.

The project workplan called for a range of activities necessary for the achievement of the primary goal:

- Review of frame and sealing technology, test methods, and existing data
- Measurement of thermal properties of relevant materials and new edge seal and frame products
- Comparison of measurement and calculation results of frame U-value
- Development of improved calculation procedures
- Design, construction and testing of low thermal loss frames
- Development of design guidelines for high performance edge seal and frames for advanced glazing applications

And consequently, the deliverables planned at the start of the project were:

* A state-of-art report on frame and edge seal thermal characteristics.
* New test results for materials and components.
* Improved computer prediction tool(s).
* A design guidance report on frame and edge seal technology for advanced glazings.
* Performance results for new frame and edge seal products.

At the start, 15 institutions from 10 countries indicated interest in participation in the project. Of those, 10 have contributed work towards the project objectives, they are listed in Appendix I. All working documents and national contributions are listed in Appendix II.

3. TECHNOLOGY STATE OF ART

Material for the state-of-art report (3) was collected by undertaking surveys among the participants, who submitted information on literature, material and product data, international and national standards, test methods and computer tools.

The final report gives a description of the thermal transfer interaction between glazing, edge seal and frame, and introduces the nomenclature used to define the thermal characteristics of windows and the window components in different standards.

New materials and products that can be applied in windows with advanced glazings are described, and performance data given when available. This work also uncovered in which areas data were missing.

The surveys resulted in 38 relevant literature references which formed the scientific basis for this report, they are listed with summaries included. The surveys also resulted in information on 24 computer tools and 5 standards with calculation methods.

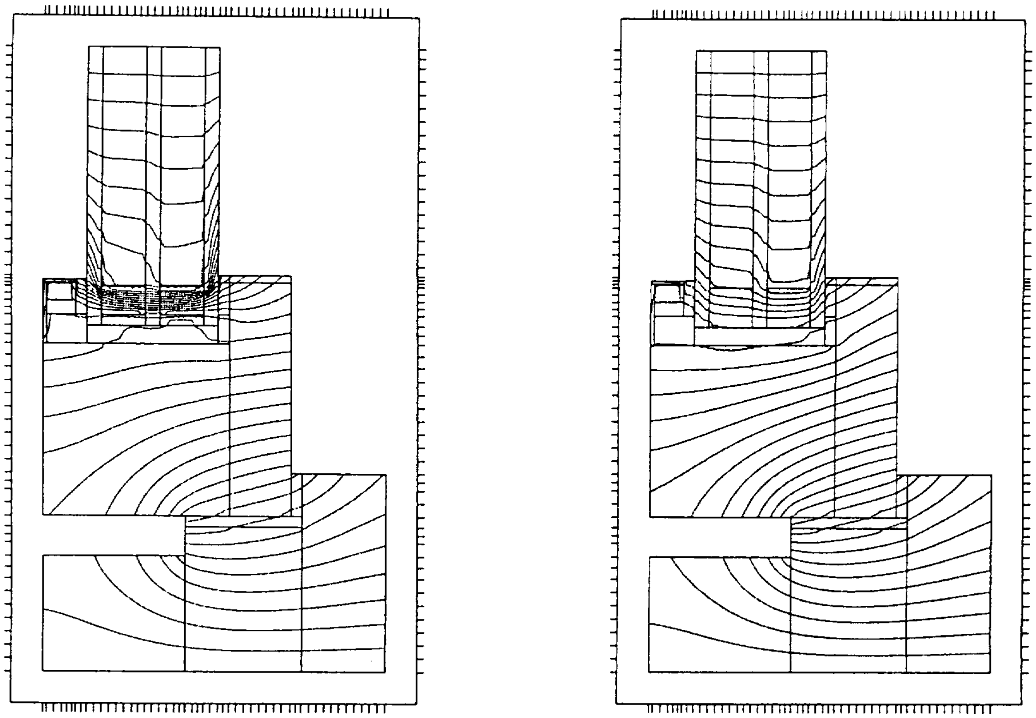

Figure 1 Heat flow pattern of the FRAME computer program for window section with conventional aluminium glazing spacer (left) and insulating foam spacer (right).

This report was the first internationally available comprehensive presentation of new technological developments in this field, and it gained quite a widespread circulation. Material from the report was also presented at the Window Innovation Conference (4). This type of information has, however, a rather limited "shelf life", as this is a very active area for development of new products.

4. TESTING NEW MATERIALS AND COMPONENTS.

The work on the state of art report (3) and the survey on requested improvements to computer tools revealed that reliable data on the thermal characteristics on new spacers and some important window materials where missing. Results from a comprehensive measurement programme conducted as a joint effort between Canadian and Swiss participants where made available to the project (5) and also published in the state of art report. Spacers and sealant materials were mounted between two sheets of glass, and tested in a heat-flow apparatus.

Specimen	**Density** [kg/m^3]	**Tm** [^{o}C]	**-T** [K]	**λ** [W/mK]
Glass 20 mm	2488	10.2	2.6	0.79
Desiccant oven dry	804	10.2	5.7	0.10
Desiccant + 6% moisture	912	10.3	8.41	0.12
ABS spacer 20 mm / Alufoil 100 mm	794	10.2	3.7	0.56
ABS spacer 15 mm / Alufoil 50 mm	750	10.3	3.7	0.52
Aluminium spacer #1 20 mm	970	10.4	2.1	2.20
Aluminium spacer #2 12 mm	965	10.5	2.1	1.35
Aluminium spacer #3 12 mm	1010	10.4	2.5	0.89
Swiggle Strip 12 mm	1156	10.4	3.1	0.63
Super Spacer 12 mm	852	10.4	5.2	0.20
Steel spacer 20 mm / 0.3 mm	1457	10.4	2.9	1.07
Polucarbonat + Alufoil	745	10.4	3.8	0.50
Butylrubber spacer 8 mm	1239	10.4	3.6	0.27
Polycarbonat spacer + Alufoil	684	10.4	7.0	0.10
Stainless steel spacer 0.15 mm	1042	10.2	7.38	0.37
ABS spacer	916	10.3	8.65	0.17
Polyisobutylene	1067	10.3	5.3	0.22
Polysulfide	1746	10.3	4.1	0.41
Silicone (2-components)	1325	10.1	4.7	0.30
Polyurethane	1519	10.2	3.8	0.40

Figure 2 Test results for the thermal conductivity of spacers, desiccants, and sealants (EMPA). Tm = mean temperature in test specimen, -T = temperature difference across whole specimen, including glass.

New advanced frames and complete windows have also been tested for thermal insulation, this work has been performed in parallel with computer simulations (see below).

5. IMPROVED COMPUTER PREDICTION TOOLS.

Many computer tools are now available that calculates the U-value of windows and the temperature distribution over the surfaces. Validation exercises have shown that for conventional windows, the tools have satisfactory accuracy, when compared to hot-box test results. The question is, of course, how well will such tools perform for advanced windows?

For this problem, a special exercise was conducted among the participants. A set of new advanced windows were analysed with hot-box measurements and computer simulations in parallel. The calculations were conducted with the Canadian programme FRAME, the KOBRU programme developed in Belgium, and the US-developed programme THERM (6).

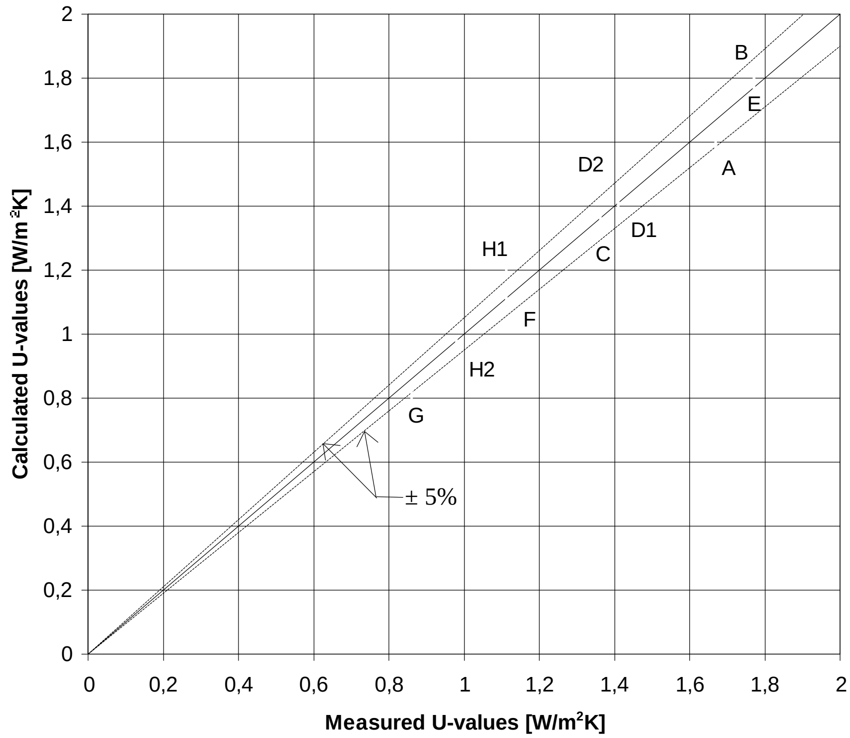

Figure 3 Comparison of measured and calculated U-values for advanced windows. Only results for comparable boundary conditions are shown. The computer tools used are also indicated.

A Scandinavian Window no. 1 (WINDOW and FRAME)
B Scandinavian Window no. 2 (WINDOW and FRAME)
C Scandinavian Window no. 3 (WINDOW and FRAME)
D Canadian Fibreglass Window
   1. Calculated in Canada (WINDOW and FRAME)
   2. Calculated in USA (WINDOW and THERM)
E Finnish Reference Window type MSE (WINDOW and FRAME)
F Finnish Super Window type SUP88/A (WINDOW and FRAME)
G Finnish Super Window type SUP88/TB/Kr (WINDOW and FRAME)
H Swiss Wood/metal Window with Integrated Shading Device
   1. With Venetian blind completely pulled up (WINDOW / FRAME and also KOBRU)
   2. With Venetian blind completely let down (WINDOW / FRAME and also KOBRU)

A survey among the participants resulted in a list of features and data that the available programmes seem to lack. Many of these suggestions for improvements have later been incorporated by the tool development organizations.

6. DEVELOPMENT OF NEW FRAME AND EDGE SEAL PRODUCTS

High performance vacuum glazing has been developed at University of Sydney, Australia, the results reported in case study B5. In Norway, a special operable frame was developed for a $1*1m^2$ sample of vacuum glazing, based on a standard wood frame window. The design was determined after careful computer calculations, and a prototype yielded a U-value of about 1.2 W/m^2*K when tested by the hot-box method, about 10% better than the calculated U-value (8).

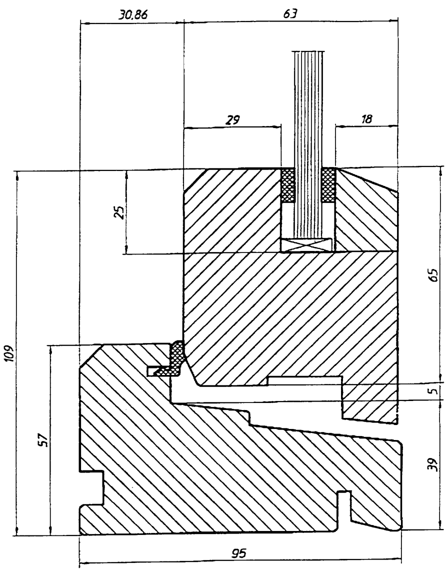

Figure 4 Section through bottom part of wood casement window with vacuum glazing.

A novel aerogel glazing has been developed in a European project, led by the Danish participants in the B9 project (9). The glazing consists of 20 mm evacuated monolithic aerogel between two pieces of low-iron glass. A special edge seal with a thin plastic foil and butyl as gas and vapour barrier was developed for the glazing, resulting in an overall U-value of about 0,4 W/m^2K for an 1*1 m^2 sample.

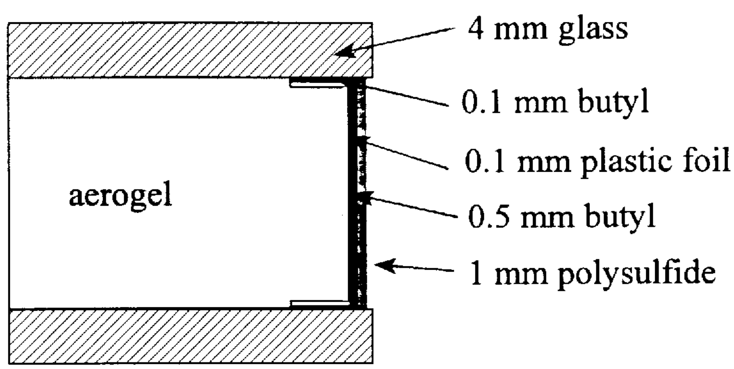

Figure 5 Edge seal design for aerogel glazing.

7. DESIGN GUIDANCE

As a final output of this project, a report was issued which gives guidance on the design of frames and edge seals for windows with advanced glazing. This is basically a re-edited version of the state of art report, with new information and data collected during the project period added. The information on standards and test methods has been updated, and only a small selection of calculation tools that are widely used is presented (7).

8. PROJECT IMPACT AND EVALUATION

It is clear that this project matter is essential to the overall success of the task, as both the Task 18 Annex and the Subtask B objectives state the importance of developing support to the application of advanced glazings, and the emphasis on large samples and whole windows is stressed. The B9 project participants are among their respective countries' national experts in this area, which should ensure scientifically top quality input to this project.

At the close of the project period, it is the judgement of the project leader that this project only partly reached its very ambitious goals. The state of art and guidance reporting have been very well received by the industry, and the interest in these reports indicates that there is a "market" for an updated version soon. New developments are introduced at such a pace that our project reports are soon outdated.

The parallel testing and simulation of advanced windows were very useful, in proving that simulations give in most cases sufficient accuracy

On the other hand, limited resources among the participants have restricted the efforts in our own developments towards new technology. It seems that the proprietary character of the results of this type of activities has also played a part here.

9. REFERENCES

1. Aschehoug, Ø.: "Case Study Working Group B9: Frame and Edge Seal Technology. Detailed Workplan 1992-04". T18/B9/WP1/92, April 1992.

2. Aschehoug, Ø.: "Case Study B9: Frame and Edge Seal Technology. Revised Project Workplan". T18/B9/WP2/94, June 1994.

3. Aschehoug, Ø., Thyholt, M., Andresen, I., & B. Hugdal: Frame and Edge Seal Technology. A State of the Art Survey". T18/B9/WD1/94, April 1994.

4. Aschehoug, Ø. & J. Baker: "Frame and Edge Seal Technology - An International Review". Window Innovations'95, Toronto. Conference Proceedings pp. 82-89, CANMET. ISBN 0-660-16085-4.

5. Ghazi Wakili,K. and Th. Frank "Thermal conductivity measurements on glass, sealant and spacer materials using a symmetrically arranged heat flow meter apparatus". T18/B9/CH1/93.

6. Andresen, I. & Ø. Aschehoug: "Combined Testing and Simulation of Frame and Edge Seals for Advanced Windows". T18/B9/WD2/96, January 1996.

7. Aschehoug, Ø., Thyholt, M., Uvsl✕kk, S. & H. Arnesen: "Frame and Edge Seal Technology. Design Guidelines". T18/B9/WD3/95, December 1995.

8. Arnesen, H., Aschehoug, Ø., Uvsl✕kk, S. & I. Aske: "Thermal Transmittance, U-value, of Wood Window with Vacuum Glazing". T18/B9/NOR2/96, September 1996.

9. Jensen, K. I., Scultz, J. M. & S. Svendsen (eds): “Development and investigation of Evacuated Windows Based on Monolithic Silica Aerogel Spacers”, Constract JOUZ-CT92-0192.

APPENDIX I

<u>Participating countries, institutions and contact persons:</u>

Country	Institution/Contact person
Canada	Enermodal Engineering Ltd/J. Baker National Research Council, IRC/ H. Elmahdy
Denmark	Thermal Insulation Laboratory, Technical University of Denmark/ S. Svendsen, K. Isaksen
Finland	VTT, Technical Research Centre of Finland/K. Hemmilä, I. Heimonen
Germany	Fraunhofer Institute for Solar Energy Systems/ W. Platzer Interpane Co./ R. Blessing
Norway	Norwegian University of Science and Technology / Ø. Aschehoug SINTEF Architecture and Building Technology/ M. Thyholt, I. Andresen, H. Arnesen Norwegian Building Research Institute/ T.Jacobsen, B. Hugdal, S. Uvsløkk, I.Aske
Switzerland	EMPA, Swiss Federal Lab for Materials Testing and Research/ Th. Frank, T. Nussbaumer, K. Ghazi Wakili
UK	Oxford Brookes University/ M.G. Hutchins Pilkington Glas Ltd/M.J. Davies Bath University, Centre for Window and Cladding Technology/ S. Ledbetter
USA	University of California, LBL/ D. Arasteh

APPENDIX II

B9 Publications:

1. Aschehoug, Ø.: "Case Study Working Group B9: Frame and Edge Seal Technology. Detailed Workplan 1992-04". T18/B9/WP1/92, April 1992.

2. Aschehoug, Ø.: "Case Study B9: Frame and Edge Seal Technology. Revised Project Workplan". T18/B9/WP2/94, June 1994.

3. Aschehoug, Ø., Thyholt, M., Andresen, I., & B. Hugdal: Frame and Edge Seal Technology. A State of the Art Survey". T18/B9/WD1/94, April 1994.

4. Aschehoug, Ø. & J. Baker: "Frame and Edge Seal Technology - An International Review". Window Innovations'95, Toronto. Conference Proceedings pp. 82-89, CANMET. ISBN 0-660-16085-4.

5. Andresen, I. & Ø. Aschehoug: "Combined Testing and Simulation of Frame and Edge Seals for Advanced Windows". T18/B9/WD2/96, January 1996.

6. Aschehoug, Ø., Thyholt, M., Uvsl✕kk, S. & H. Arnesen: "Frame and Edge Seal Technology. Design Guidelines". T18/B9/WD3/95, December 1995.

7. Arnesen, H: "Calculated U-value for Swiss Wood/Metal Window with Integrated Shading Device". T18/B9/NOR1/95

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12. Baker, J. "Simulated U-values and Energy Rating of a Canadian Fibreglass Window". T18/B9/CAN2/95

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15. Nussbaumer, T and Th. Frank: "Surface temperature measurements on insulated glass units with four different types of spacers. T18/B9/CH2/93

16. Frank, T: "Thermal conductivity measurements". T18/B9/CH3/95

17. K. Ghazi Wakili and Th. Frank: "Thermal transmittance of a wood/metal window with integrated shading device (Tobtherm Vario)", T18/B9/CH4/95

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20. Aschehoug, Ø.: "Frame and Edge Seal Technology. Final Project Report". T18/B9/FRP/97.